E-80111

EXHAUST SYSTEM

Cross-Reference to Related Application:

This application is a continuation of copending International Application No. PCT/EP01/11744, filed October 11, 2001, which designated the United States and was not published in English.

Background of the Invention:

Field of the Invention:

The present invention relates to an exhaust gas system for purifying an exhaust gas from an internal combustion engine, in particular for purifying exhaust gases from a diesel engine of an automobile.

Such exhaust systems have been the subject of ongoing development in the past, due to statutory provisions which are imposing ever higher demands on the exhaust systems used in automotive engineering. That has involved using a wide range of components which each fulfill different functions within the exhaust system. For example, starting catalytic converters are known which have a particularly small volume, so that they quickly reach their starting temperature required for catalytic conversion following a cold start of the internal combustion engine. Furthermore, by way of example,

electrically heatable catalytic converters are known, which likewise allow an improved cold-starting performance of the exhaust system. What are known as adsorbers in the exhaust system of an internal combustion engine have the task of adsorbing certain pollutants which are present in the exhaust gas for a certain period of time. Those pollutants are preferably stored until a downstream catalytic converter has reached its operating temperature. Moreover, in particular in exhaust systems of diesel engines, particulate traps or particulate filters are used, which collect carbon-based particulates contained in the exhaust gas. The collected particulates are converted continuously or discontinuously, for example by supplying a high level of thermal energy.

Summary of the Invention:

It is accordingly an object of the invention to provide an exhaust system for purifying exhaust gas from an internal combustion engine, in particular for purifying exhaust gases from a diesel engine of an automobile, which overcomes the hereinafore-mentioned disadvantages of the heretofore-known devices of this general type and which ensures particularly effective conversion of pollutants that are present in the exhaust gas, ensuring continuous regeneration of a particulate trap disposed in the exhaust system.

With the foregoing and other objects in view there is provided, in accordance with the invention, an exhaust system for purifying or cleaning exhaust gas from an internal combustion engine, in particular from a diesel engine of an automobile, which can flow through the exhaust system in a preferred flow direction in order to be purified. The exhaust system includes the following successive components, as seen in the flow direction:

1. a catalytic converter, in particular for converting carbon monoxides and hydrocarbons contained in the exhaust gas;

2. an oxidation catalytic converter, in particular for converting nitrogen monoxide contained in the exhaust gas; and

3. a particulate trap for collecting particulates contained in the exhaust gas.

The proposed configuration of the above-mentioned components in the exhaust system has particularly beneficial effects with regard to the regeneration of the particulate trap. These positive effects result unexpectedly from the above-mentioned components being connected in series, as will be explained in more detail below.

The upstream catalytic converter is used in particular to convert carbon monoxides and hydrocarbons. The overall carbon monoxide content in the exhaust gas from diesel engines is relatively low and only increases relatively strongly as it approaches the particulate limit. This is caused in particular by the generally lean operating strategy (with excess air) of the diesel engine with a view to fuel consumption. In this case, high levels of hydrocarbons are caused, for example, in excessively lean fuel/air mixture ranges, and these cannot be converted in time at low temperatures in the combustion chamber (in partial-load mode). An increase in the hydrocarbon contents in the exhaust gas is also present in the event of temporarily very rich combustion (with a deficit of air). The catalytic converter, in particular when it is disposed close to the engine, preferably converts very specific pollutants contained in the exhaust gas (in particular carbon monoxide and unsaturated hydrocarbons). These processes take place quickly and virtually completely due to the high temperatures in the vicinity of the engine.

The oxidation catalytic converter disposed downstream is used in particular to convert nitrogen oxides which are still present in the exhaust gas, due to the fact that the catalytic converter has already converted the majority of the carbon monoxides and unsaturated hydrocarbons. High levels of nitrogen oxides are produced in particular in the case of

virtually stoichiometric combustion through to a moderate excess of air (approximately up to $\lambda = 3$). In this case, the nitrogen dioxide content in the exhaust gas is usually between 5 and 15%. The oxidation catalytic converter thus has a catalytically active coating, which converts the nitrogen monoxides into nitrogen dioxides. This causes the nitrogen dioxide content in the exhaust gas to be increased considerably, preferably to a level of greater than 50%, in particular over 80% or even 95%, in the exhaust gas. Conversion rates of this nature are achieved because the catalytic converter disposed upstream has already substantially converted further pollutants into harmless constituents. The high nitrogen dioxide content produced in this way by the oxidation catalytic converter has a particularly beneficial effect with regard to the regeneration of the downstream particulate trap.

Particulates, in particular carbon-based particulates, are present in the exhaust gas when the fuel is burnt with an extreme deficit of air and, due to the locally very inhomogeneous fuel-air mixture, are typical of combustion in the diesel engine. The particulates usually tend to be deposited at the coatings of the components and/or at the outer wall, such as for example in the exhaust section, of the exhaust system. Then, in the event of load changes, they are expelled in the form of a cloud of particulates. As a result

of diffusion and adsorption phenomena, these particulates are retained and continuously chemically converted by the particulate trap, which according to the invention is disposed downstream. This ensures continuous regeneration of the particulate trap and prevents flow paths in the interior of the particulate trap from becoming blocked. This regeneration process is promoted surprisingly effectively by the nitrogen dioxide which has previously been generated by the oxidation catalytic converter. Consequently, on one hand effective conversion of the carbon-based particulates is ensured, and on the other hand an increase in pressure in the exhaust system as a result of blocked flow paths is avoided. In this context, it is preferable for all of the components to be disposed close to the engine, i.e. in particular not at the underbody of an automobile. This ensures sufficiently high temperatures over the operating life of the internal combustion engine (even immediately after a cold start), so that the exhaust emission guidelines which currently apply can be complied with by some distance with regard to the individual pollutants remaining in the exhaust gas.

In accordance with another feature of the invention, there is provided a turbocharger. The catalytic converter is disposed upstream of the turbocharger, and the oxidation catalytic converter is disposed downstream of the turbocharger, as seen in the flow direction. Turbocharging is a way of increasing

the power of an internal combustion engine, which is used in particular in conjunction with diesel engines. During the turbocharging, a work-performing machine compresses the air required for the engine combustion process, so that a greater mass of air passes into the cylinder or combustion chamber per cycle of the internal combustion engine. For this purpose, the compressor is driven, for example, by a turbocharger which utilizes the energy of the exhaust gas. The coupling to the engine is not mechanical in this case, but rather purely thermal, and in the automotive industry it is primarily the principle of ram charging which is employed. Placing the catalytic converter upstream of a turbocharger of this nature ensures that the operating temperature of the catalytic converter is reached very quickly, since in this way dissipation of heat from the exhaust gas as a result of contact with components of the turbocharger is avoided. Moreover, this ensures that the catalytic converter is disposed close to the engine. In this context, it is particularly advantageous for the catalytic converter to be directly connected to the internal combustion engine and in particular to be disposed in an exhaust manifold. It is also possible for a plurality of small converters each to be fitted in a separate exhaust section of an exhaust manifold, in which case they are preferably secured directly at or to a connection point of the exhaust manifold and the internal combustion engine. The thermal light-off performance of the

catalytic converter is significantly enhanced by the proximity to the combustion chambers or the cylinders of the internal combustion engine.

In accordance with a further feature of the invention, the oxidation catalytic converter has at least two zones. The zone which is furthest away from the internal combustion engine is constructed with a higher specific heat capacity than the others of the at least two zones. The oxidation catalytic converter usually has a honeycomb structure, in which case partitions form passages through which an exhaust gas can flow. The increase in the specific heat capacity (in particular the surface area-specific heat capacity) can be ensured, for example, by making the partitions thicker. For example, if the partitions in the upstream zone of the oxidation catalytic converter have a thickness of less than 0.03 mm, the partitions in a central zone have a thickness of approximately 0.03 to 0.06 mm, while a downstream zone is constructed, for example, with a partition thickness of at least 0.08 mm. The number of zones and the thickness of the partitions is to be oriented in particular to the specific composition of the exhaust gas and its thermal energy. The increase in the specific heat capacity in the flow direction means that the oxidation catalytic converter in upstream zones reaches its operating temperature at a very early stage, with the catalytic reaction which is induced there delivering

sufficient exothermic energy for the downstream zones likewise to be heated rapidly. In this case, the zone with the high heat capacity represents a type of heat storage device even after the internal combustion engine has been switched off, so that, for example, the cold-start phase after a restart is significantly shortened.

In accordance with an added feature of the invention, the particulate trap is disposed directly downstream of the oxidation catalytic converter, preferably at a distance of less than 50 mm, in particular even less than 20 mm, as seen in the flow direction. If the exhaust system is configured in this way, it is particularly advantageous to accommodate the oxidation catalytic converter and the particulate trap in a common housing. In this context, preference is given to an embodiment in which the oxidation catalytic converter is integrated in the particulate trap and the particulate trap preferably has a catalytically active coating. This allows a particularly space-saving configuration of oxidation catalytic converter and particulate trap, which is important especially with a view toward placing the exhaust system close to the engine.

In accordance with an additional feature of the invention, the particulate trap has an overall volume (walls plus cavities) of less than 75% of a volumetric capacity of the internal

combustion engine, in particular less than 50% and preferably even less than 25%. Under certain circumstances, such as for example when disposed close to the engine and/or during a very brief, discontinuous regeneration of the particulate trap, it is even possible for the overall volume to be reduced still further, if appropriate to a size of less than 5% or even 1% of the volumetric capacity of the internal combustion engine. In this context, the term volumetric capacity is to be understood as meaning the sum of the volumes of the cylinders or combustion chambers of the internal combustion engine in which the combustion of the fuel takes place.

The particulate trap therefore has a very small overall volume, which on one hand ensures a space-saving configuration and on the other hand ensures effective chemical conversion of the particulates. The particulate trap may in particular be constructed to be this small due to the fact that the upstream oxidation catalytic converter produces so much nitrogen dioxide that continuous regeneration of the particulate trap is ensured and there is no need for a large storage volume for carbon-based particulates which are yet to be converted.

In accordance with yet another feature of the invention, it is particularly advantageous for the particulate trap to have freely accessible passages in which turbulence points and calming points and/or diverter devices are disposed. This

increases the probability of particulates reacting with nitrogen oxide in a simple way by lengthening the residence time of particulates (in particular carbon-based particulates) in the particulate trap. This is achieved, in the case of flow paths which are inherently freely accessible, by having a sufficient number of turbulence and calming points and/or diversions, promoting the deposition of the particulates at the walls. While a particle which flies along in the exhaust-gas stream has only a slight chance of reacting with other constituents of the exhaust gas, this chance increases immensely if the particle is stopped in a turbulence or calming point or is deposited at a partition. All of the nitrogen dioxides moving past are then available for reaction, so that the particulates are rapidly broken down. Consequently, the particulate trap cannot become blocked, but rather is constantly regenerated.

In accordance with yet a further feature of the invention, the catalytic converter has a converter volume which is at most half a catalytic converter volume of the oxidation catalytic converter. The terms converter volume and catalytic converter volume in each case mean the external volumes (walls plus passages) of the at least one converter or of the oxidation catalytic converter. Such a small configuration of the catalytic converter assists with the light-off performance and also promotes a space-saving configuration.

In accordance with a concomitant feature of the invention, at least one and preferably each component of the exhaust system has a honeycomb structure with passages through which an exhaust gas can flow. The honeycomb structure is formed by at least partially structured metal foils. The honeycomb structure of the converter and/or of the oxidation catalytic converter in this case has a passage density of at least 600 cpsi (cells per square inch), in particular greater than 1000 cpsi. The particulate trap may require slightly larger passage cross sections, meaning that it is to be constructed with a passage density of greater than 200 cpsi, in particular 400 cpsi or 600 cpsi, in which case a sufficient surface area to accumulate the particles is always available. If the oxidation catalytic converter is constructed with a honeycomb structure including metal foils of this nature, the metal foils preferably have a thickness of less than 0.06 mm, in particular less than 0.03 mm.

Other features which are considered as characteristic for the invention are set forth in the appended claims.

Although the invention is illustrated and described herein as embodied in an exhaust system, it is nevertheless not intended to be limited to the details shown, since various modifications and structural changes may be made therein

without departing from the spirit of the invention and within the scope and range of equivalents of the claims.

The construction and method of operation of the invention, however, together with additional objects and advantages thereof will be best understood from the following description of specific embodiments when read in connection with the accompanying drawings.

Brief Description of the Drawings:

Fig. 1 is a diagrammatic, perspective view of an embodiment of an exhaust system according to the invention;

Fig. 2 is an enlarged plan view of a component of the exhaust system with a honeycomb structure;

Fig. 3 is a further enlarged, fragmentary, perspective view of an embodiment of the exhaust system particulate trap; and

Fig. 4 is an elevational view of a further embodiment of the exhaust system according to the invention disposed close to the engine.

Description of the Preferred Embodiments:

Referring now to the figures of the drawings in detail and first, particularly, to Fig. 1 thereof, there is seen a

diagrammatic and perspective view of an exhaust system 1 for purifying exhaust gas from a diesel engine. In this system, the exhaust gas, starting from the internal combustion engine or diesel engine 2, flows through the exhaust system 1 in a preferred flow direction 3. The exhaust system 1 includes, in succession in the flow direction 3, a catalytic converter 4, in particular for converting carbon monoxides and hydrocarbons contained in the exhaust gas, an oxidation catalytic converter 5, in particular for converting nitrogen monoxides contained in the exhaust gas, and a particulate trap 6 for collecting particulates, in particular carbon-based particulates, contained in the exhaust gas. Since the illustrated exhaust system 1 in some cases has a plurality of exhaust sections upstream of a turbocharger 7, the illustrated embodiment is equipped with two catalytic converters 4 which are disposed very close to the internal combustion engine 2. In this case, it is also possible to place the catalytic converters 4 in the exhaust sections of one or more exhaust manifold 8 which is directly connected to the internal combustion engine 2. The illustrated oxidation catalytic converter 5 has a plurality of zones 9. The zones 9 have an increasing specific heat capacity as seen in the flow direction 3 of the exhaust gas. The particulate trap 6 is disposed immediately downstream of the oxidation catalytic converter 5, at a distance 10 of less than 50 mm, as seen in the flow direction 3. The particulate trap 6 in this case has a total volume 11 which is preferably

less than 75% of a volumetric capacity 12 of the internal combustion engine 2. The volumetric capacity 12 corresponds to the sum of individual volumes of cylinders 21 of the internal combustion engine 2. Furthermore, the catalytic converters 4 are constructed with a converter volume 17 which is at most half a catalytic converter volume 18 of the oxidation catalytic converter 5. In this case, the term converter volume 17 is to be understood as meaning the sum of the volumes of the catalytic converters 4.

The illustrated exhaust system 1 is preferably to be disposed in the immediate vicinity of the internal combustion engine 2. In this context, it is important in particular to avoid one of the components 4, 5, 6 being disposed in the underbody of an automobile.

Fig. 2 shows a plan view of a catalytic converter 4 or an oxidation catalytic converter 5 with a honeycomb structure 19. The honeycomb structure 19 has passages 13 through which an exhaust gas can flow and is formed through the use of at least partially structured metal foils 20. For this purpose, smooth metal foils 23 and structured metal foils 20 were initially stacked and then wound up, with the honeycomb structure 19 being disposed in a tubular casing 22 in order to increase the stability of the component. The honeycomb structure 19 is preferably constructed with a catalytic coating, which is

distinguished in particular by a very fissured surface and consequently also by a high level of efficiency with regard to the conversion of pollutants.

Fig. 3 shows a fragmentary, diagrammatic and perspective view of a particulate trap 6. The particulate trap 6 is composed of a structured metal foil 20 and of a smooth metal foil 23 with apertures 24 and forms freely accessible passages 13. Wing-shaped diverter devices 16 with openings 25 lead to the effects which have been described above. The diverter devices 16 have calming points 15 and turbulence points 14. The diverter devices 16 swirl up the exhaust gas so that the particles remain in the particulate trap 6 longer and therefore find it easier to react with other constituents of the exhaust gas. Depending on the precise configuration of the diverter devices 16, particulates are also thrown onto the metal foils 20 and 23, where they continue to stick. There, the carbon-based particulates are chemically converted by the nitrogen dioxide flowing through so continuously and effectively that free flow through the passages is ensured at any time.

Fig. 4 diagrammatically depicts a further configuration of the exhaust system 1 disposed close to the engine 2. The exhaust system 1 is used to purify exhaust gas from the internal combustion engine 2, in particular a diesel engine of an

automobile, and the exhaust gas flows through it in a flow direction 3. The exhaust system 1 includes, in succession in the flow direction 3, at least one catalytic converter 4, in particular for converting carbon monoxides and hydrocarbons contained in the exhaust gas, an oxidation catalytic converter 5, in particular for converting nitrogen monoxide contained in the exhaust gas, and a particulate trap 6 for collecting particulates contained in the exhaust gas. In the embodiment shown, the catalytic converters 4 are disposed particularly close to the combustion chambers of the engine, and specifically there is a small catalytic converter 4 disposed in each outlet from the combustion chambers in an exhaust manifold 28. Therefore, the catalytic converters 4 are even connected upstream of the turbocharger 7, which is constructed in particular as an exhaust-gas turbocharger, and which is used to compress fresh air supplied to the engine (fresh air supply 27).

In the case of the illustrated exhaust system 1, the oxidation catalytic converter 5 and the particulate trap 6 are disposed in a common housing 26, with the oxidation catalytic converter 5 being integrated in the particulate trap 6. For this purpose, the particulate trap 6 has a catalytically active coating in the same way as the oxidation catalytic converter 5. The particulate trap 6 still has an overall volume 11 which is less than 75% of a volumetric capacity 12 of the

internal combustion engine 2, in particular less than 50% and preferably even less than 25%. In order to ensure that the highest possible temperatures are present for the purpose of regenerating the particulate trap 6 during operation of the internal combustion engine 2 and of the exhaust installation 1, the particulate trap 6 is disposed at a distance L from the engine. This distance L is preferably less than 80 cm. In this context, the distance L is preferably to be understood as meaning a path length covered by the exhaust gas before it reaches the particulate trap 6.

The exhaust system according to the invention ensures very effective conversion of pollutants contained in the exhaust gas from a diesel engine (in particular carbon monoxide, unsaturated hydrocarbons, nitrogen oxides, carbon-based particulates), and in addition has a particularly positive effect with regard to the regeneration of the particulate trap. More accurately, the increased production of nitrogen dioxide by the oxidation catalytic converter, due to the upstream catalytic converter, means that a sufficient quantity of nitrogen dioxide is made available to the particulate trap to ensure continuous regeneration. This prevents blocked passages and means that emissions are well below the current exhaust emissions limits.